Fermilab FERMILAB-Conf-00/116-E CDF/D0 June 2000

DIFFRACTION RESULTS FROM THE TEVATRON

K. HATAKEYAMA
The Rockefeller University, 1230 York Avenue,
New York, NY, 10021, U.S.A.
for the CDF and DØ Collaborations

Recent results on dijet production in single diffraction and double pomeron exchange at the Tevatron are presented. Single diffraction results are compared with predictions from Monte Carlo models and expectations from results obtained in diffractive deep inelastic scattering experiments at HERA. Double pomeron exchange results are compared with corresponding single diffraction results to test factorization.

1 Introduction

Recent results obtained in hard single diffraction (SD) and double pomeron exchange (DPE) studies by the CDF and DØ collaborations at the Fermilab Tevatron collider are reported. Hard SD events are characterized by a hard scattering and a leading (anti)proton adjacent to a forward rapidity gap, defined as a pseudorapidity region devoid of particles. In hard DPE events, both proton and antiproton survive the collision and are separated by rapidity gaps from a hard scattering occurring in the central region. A rapidity gap is presumed to be associated with the exchange of a Pomeron, which is a color-singlet state with vacuum quantum numbers.

The central issue in this field is whether hard diffraction processes obey QCD factorization, i.e. can be described in terms of parton-parton scattering cross sections convoluted with a universal diffractive (anti)proton structure function. Experiments at the ep collider HERA [1,2] and at $\bar{p}p$ colliders [3,4] have previously characterized hard diffraction. The results presented in this paper provide new insight into the mechanism of diffractive hard interactions and on the question of QCD factorization for hard diffraction process.

2 Hard Diffraction with a Rapidity Gap

The DØ collaboration has measured the fraction of forward and central dijet events that contain forward rapidity gaps at $\sqrt{s} = 630$ and 1800 GeV. Two different triggers were used: a forward jet trigger (two 12 GeV jets with $|\eta| > 1.6$) and an inclusive jet trigger (two 15 GeV jets at 1800 GeV and 12 GeV jets at 630 GeV) with an offline cut of $|\eta| < 1.0$. The forward scintillator arrays (LØ detector), which provide partial coverage within $2.3 < |\eta| < 4.3$, and a portion of the two forward calorimeters ($3.0 < |\eta| < 5.2$) are used to identify rapidity gaps in SD events. The gap fraction was extracted by implementing a simultaneous two-dimensional fit to the multiplicity distributions n_{CAL} and $n_{\mathrm{L}\emptyset}$ for both background and signal, where n_{CAL} and $n_{\mathrm{L}\emptyset}$ are the number of forward calorimeter towers and LØ scintillation tiles containing a signal, respectively. The results are shown in Table 1. The gap fractions predicted by the hard SD event generator POMPYT [5] with four different pomeron structure functions, (1) "hard gluon", $s(\beta) \propto \beta(1-\beta)$; (2) "flat gluon", $s(\beta) \propto$ constant; (3) "soft gluon", $s(\beta) \propto (1-\beta)^5$; and (4) "quark", the two quark analog of (1), are also shown in Table 1, where β is the momentum fraction of the Pomeron carried by a parton. Monte Carlo rates for hard and flat gluon structures were found to be far higher than supported by data, while the quark structure is in reasonable agreement with the data. However, the quark structure has previously been shown to predict an excessive rate of diffractive W production at $\sqrt{s} = 1800$ GeV [4]. The lower half of Table 1 provides new information, since the Monte Carlo normalization cancels for the same $\sqrt{s}$. A gluonic Pomeron containing significant soft and hard components, combined with a reduced (renormalized [6]) pomeron flux factor, could reasonably describe all the data samples.

Table 1: The measured and predicted gap fractions and their ratios.

		Gap Fraction			
Sample	Data	Hard Gluon	Flat Gluon	Soft Gluon	Quark
1800 GeV $\|\eta\| > 1.6$	$(0.65 \pm 0.04)\%$	$(2.2 \pm 0.3)\%$	$(2.2 \pm 0.3)\%$	$(1.4 \pm 0.2)\%$	$(0.79 \pm 0.12)\%$
1800 GeV $\|\eta\| < 1.0$	$(0.22 \pm 0.05)\%$	$(2.5 \pm 0.4)\%$	$(3.5 \pm 0.5)\%$	$(0.05 \pm 0.01)\%$	$(0.49 \pm 0.06)\%$
630 GeV $\|\eta\| > 1.6$	$(1.19 \pm 0.08)\%$	$(3.9 \pm 0.9)\%$	$(3.1 \pm 0.8)\%$	$(1.9 \pm 0.4)\%$	$(2.2 \pm 0.5)\%$
630 GeV $\|\eta\| < 1.0$	$(0.90 \pm 0.06)\%$	$(5.2 \pm 0.7)\%$	$(6.3 \pm 0.9)\%$	$(0.14 \pm 0.04)\%$	$(1.6 \pm 0.2)\%$
		Ratio of Gap Fraction			
630/1800 $\|\eta\| > 1.6$	1.8 ± 0.2	1.7 ± 0.4	1.4 ± 0.3	1.4 ± 0.3	2.7 ± 0.6
630/1800 $\|\eta\| < 1.0$	4.1 ± 0.9	2.1 ± 0.4	1.8 ± 0.3	3.1 ± 1.1	3.2 ± 0.5
1800 $\|\eta\| > 1.6/\|\eta\| < 1.0$	3.0 ± 0.7	0.88 ± 0.18	0.64 ± 0.12	$30. \pm 8.$	1.6 ± 0.3
630 $\|\eta\| > 1.6/\|\eta\| < 1.0$	1.3 ± 0.1	0.75 ± 0.16	0.48 ± 0.12	$13. \pm 4.$	1.4 ± 0.3

3 Diffractive Dijets with a Leading Antiproton

The CDF collaboration has studied single diffractive dijet production using events triggered on a leading antiproton by Roman Pot spectrometers. The main goal of this study is to measure the diffractive structure function of the antiproton and compare it with expectations from results obtained in diffractive deep inelastic scattering (DDIS) experiments at HERA to test factorization. In leading order QCD, the ratio $R(x)$ of the diffractive to non-diffractive (ND) rates as a function of x is equal to the ratio of the antiproton diffractive to ND structure functions, where x is the momentum fraction of the antiproton carried by the struck parton. The associated structure functions will be denoted by $F_{JJ}(x) = x[g(x) + \frac{4}{9}q(x)]$, where $g(x)$ and $q(x)$ are the gluon and quark densities, respectively. Thus, the diffractive structure function may be obtained by multiplying the known ND structure function by $R(x)$. The value of x is evaluated from the jet kinematics (including a third jet if $E_T^{jet3} > 5$ GeV) as $x = \sum_{i=1,2(3)} E_T^i e^{-\eta^i}/\sqrt{s}$. The obtained diffractive structure function $F_{JJ}^D(x)$ can be written as a function of $\beta = x/\xi$, where ξ is the fractional momentum loss of the antiproton. Fig. 1 shows the measured $F_{JJ}^D(\beta)$ in the region $|t| < 1$ GeV^2 and $0.035 < \xi < 0.095$ and the fit $F_{JJ}^D \propto 1/\beta^{1.08}$ in the region $\beta < 0.5$. The dashed (dotted) curve is the expectation for $F_{JJ}^D(\beta)$ from fit 2 (fit 3) of the H1 diffractive structure function evaluated at $Q^2 = 75$ GeV^2, which approximately corresponds to the $\langle E_T^{jet}\rangle^2$ of the CDF data. The measured and expected β distributions disagree both in normalization and shape. The discrepancy in normalization, defined as the ratio of the integral over β of data to expectation, is $D = 0.06 \pm 0.02$ (0.05 ± 0.02) for fit 2 (fit 3). The disagreement between the measured diffractive structure function and the expectation from DDIS represents a breakdown of factorization.

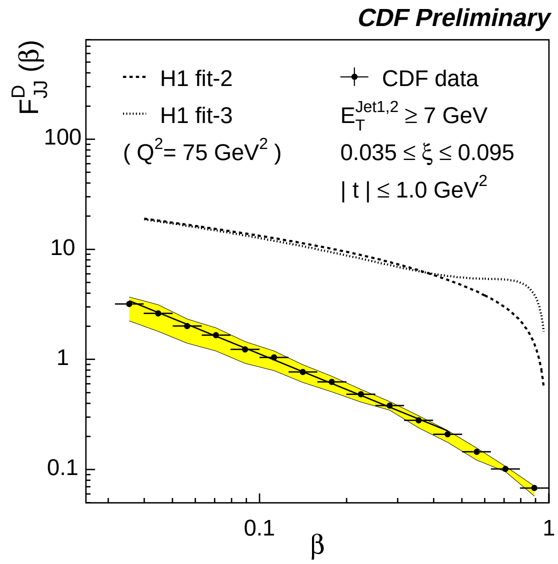

Figure 1: Data β distribution (points) compared with expectations from the parton densities of the proton extracted from diffractive deep inelastic scattering by the H1 collaboration. The straight line is a fit to the data of the form β^{-n} in the region $\beta < 0.5$. The lower (upper) boundary of the filled band represents the data distribution obtained by using only the two leading jets (up to four jets of $E_T > 5$ GeV) in evaluating β. The dashed (dotted) lines are expectations from the H1 fit 2 (fit 3). The systematic uncertainty in the data normalization is $\pm 25\%$.

4 Dijet Production in Double Pomeron Exchange

Dijet production in DPE has been studied by both CDF and DØ collaborations. The CDF collaboration has observed dijet production in DPE in a sample of events triggered on a leading antiproton and requiring a forward rapidity gap in the forward calorimeter (FCAL) and beam-beam counter (BBC) on the proton side. The FCAL and BBC cover the regions $2.4 < |\eta| < 4.2$ and $3.2 < |\eta| < 5.9$, respectively.

Factorization can be tested by comparing the ratio $R_{ND}^{SD}(x_{\bar{p}})$ of the number of SD to ND dijet rates as a function of $x_{\bar{p}}$, with the ratio $R_{SD}^{DPE}(x_p)$ of the DPE to SD rates as a function of x_p; the ratios $R_{SD}^{DPE}(x_p)$ and $R_{ND}^{SD}(x_{\bar{p}})$ are, in leading QCD, equal to the ratio of SD to ND structure functions. The variables x_p and $x_{\bar{p}}$ are the momentum fraction of the parton in the proton and antiproton, respectively. In Fig. 2, the ratio $R_{SD}^{DPE}(x_p)$ is compared with the ratio $R_{ND}^{SD}(x_{\bar{p}})$ as a function of $x(\equiv x_p = x_{\bar{p}})$, where the ratios $R_{SD}^{DPE}(x_p)$ and $R_{ND}^{SD}(x_{\bar{p}})$ are normalized per unit ξ. The insert of Fig. 2 shows the ξ-dependence of the ratios $\tilde{R}(x)$, where the tilde over the R indicates the weighted average of the points in the region of x within the vertical dashed lines in the main figure. By taking the extrapolation of a straight line fit to the six $\tilde{R}_{ND}^{SD}$ ratios, the double ratio of $\tilde{R}_{ND}^{SD}$ to $\tilde{R}_{SD}^{DPE}$ is found to be $D \equiv \tilde{R}_{ND}^{SD}/\tilde{R}_{SD}^{DPE} = 0.19 \pm 0.07$. The deviation of D from unity indicates a breakdown of factorization.

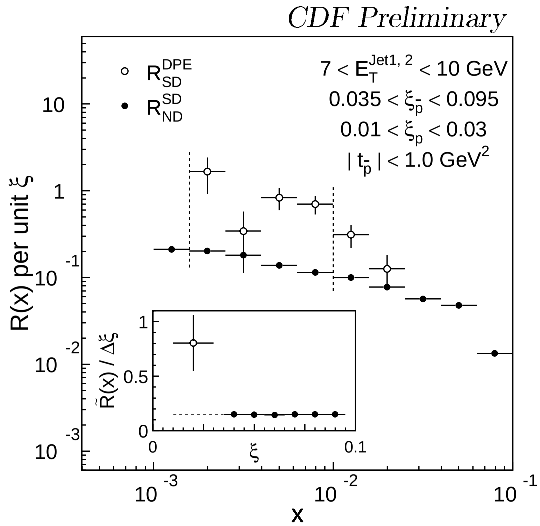

Figure 2: Ratios of DPE to SD (SD to ND) dijet event rates per unit ξ, shown as open (filled) circles, as a function x-Bjorken of partons in the p ($\bar{p}$). The errors are statistical only. The SD/ND ratio has a normalization uncertainty of $\pm 20\%$. The insert shows $\tilde{R}(x)$ per unit ξ versus ξ, where the tilde over the R indicates the weighted average of the $R(x)$ points in the region of x within the vertical dashed lines, which mark the DPE kinematic boundary (left) and the value of $x = \xi_p^{min}$ (right).

5 Conclusion

The DØ collaboration has measured the gap fractions at $\sqrt{s} = 630$ and 1800 GeV without applying model-dependent corrections. Although the DØ data can be reasonably described within the Ingelman-Schlein model [7] by a Pomeron composed mainly of quarks, to take into account previous measurements, a reduced (renormalized) flux convoluted with a gluonic Pomeron containing significant soft and hard components is required.

The CDF collaboration has measured the diffractive structure function $F_{JJ}^D(\beta)$ using SD dijet events at $\sqrt{s} = 1800$ GeV. For $\beta < 0.5$, the $F_{JJ}^D(\beta)$ varies as $\sim 1/\beta$. In comparing $F_{JJ}^D(\beta)$ with expectations from results obtained in DDIS experiments, a discrepancy is found both in normalization and shape of the β distribution, indicating a breakdown of factorization.

The CDF collaboration has also studied dijet production in DPE and tested factorization by comparing the ratio of SD to ND rates with the ratio of DPE to SD rates. A disagreement found between the ratios of SD/ND and DPE/SD rates represents a breakdown of factorization.

References

1. M. Derrick *et al.*, (ZEUS Collaboration), *Z. Phys.* C **68**, 569 (1995); *Phys. Lett.* B **356**, 129 (1995); *Eur. Phys. J.* C **6**, 43 (1999).
2. C. Adloff *et al.*, (H1 Collaboration), *Z. Phys.* C **76**, 613 (1997); *Eur. Phys. J.* C **6**, 421 (1999).
3. A. Brandt *et al.*, (UA8 Collaboration), *Phys. Lett.* B **297**, 417 (1992); B **421**, 395 (1998).
4. F. Abe *et al.*, (CDF Collaboration), *Phys. Rev. Lett.* **78**, 2698 (1997); 79, 2636 (1997); T. Affolder *et al.*, *Phys. Rev. Lett.* **84**, 232 (2000).
5. P. Bruini and G. Ingelman, DESY 93-187, 1993.
6. K. Goulianos, *Phys. Lett.* B **358**, 379 (1995); B **363**, 268 (1995).
7. G. Ingelman and P. Schlein, *Phys. Lett.* B **152**, 256 (1985).